A Development Architecture for the Intelligent Animal Care and Management System Based on the Internet of Things and Artificial Intelligence

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***Abstract*—The zoo is a local facility where some wild or exotic animals are placed in a fence. The main significance of the zoo is to provide educational and animal conservation functions, and secondly to provide public viewing and entertainment. Animal care and management in the zoo is almost open all year round. Its basic tasks include accommodation, breeding, health care, and medical care etc. Because there are nearly hundreds, thousands, or even ten thousands animals with different body shape and characteristics in the zoo that need to be cared for and managed, animal administrators must be skilled in various tools and real time control the condition of all animals, resulting in the heavy workload of the animal administrators and the huge operating expenses of the zoo. Therefore, it is necessary to find ways to reduce the workload of the animal administrators, but also to immediately control the current state of the animals, while saving animal care and management expenses. This study proposes a development architecture for the intelligent animal management system based on the Internet of Things (IoT) and artificial intelligence (AI). Its main purpose is to automate some tedious procedures for caring animals through the IoT and AI to help animal administrators to take care of them and manage them more systematically.**

Keywords—zoo, animal care and management, internet of things, artificial intelligence, automation

I. INTRODUCTION

There are zoos in many big cities in the world. The zoo is a place where some wild or exotic animals are placed in fences. The main purpose of the establishment is to provide educational purposes and animal conservation, and secondly to provide public viewing and entertainment. According to the Association of Zoos and Aquariums, there are more than 181 million visitors a year in the United States of America (USA), more than the annual attendance of NFL, NBA, NHL and MLB. In addition, according to the survey results, 93% agreed that their families like to see animals in zoos and aquariums; 94% believe that zoos and aquariums teach children how to protect animals and the habitats they depend on; 79% companies that support zoo and aquarium wildlife conservation feel better; 66% of respondents are more likely to buy products and services from these companies [1]. However, before getting the benefits of these zoos, we should consider the animal care and management behind them. Different zoos, depending on the size of their place, may have nearly hundreds, thousands, or even ten thousands animals with different body shape and characteristics need to be cared for and managed, animal administrators must be proficient in tools and real time control the condition of all animals creates a heavy workload for animal administrators and a huge operating expense for the zoo. In view of this, the integration of modern information and communication technology will help solve this problem. Currently on the market, information technology products have been available based on IoT technology for the care of animal cats and dogs that are closest to humans.

Lucky Tag smart collar [2] was proposed by Taiwanese Airyzonen, which has the function of tracking pet activities and health monitoring, and also has the function of missing and searching. By observing the long-term trend of pets, Lucky Tag allows owners to detect changes in activity early and seek professional medical assistance. Recently, the Yamato Zoo in Sapporo, Japan, in cooperation with Hokkaido University, began to use artificial intelligence (AI) systems to analyze animal behavior patterns through image recognition, improve animal support environment and effectively monitor animal health [3]. A team of researchers from Harvard University, Auburn University, the University of Wyoming, the University of Oxford, and the University of Minnesota proved that the AI technology can be used to identify animal images captured by motion-sensing cameras [4]. They have used Snapshot Serengeti datasets that have deep learning to identify 3.2 million wildlife photos, recognizing that the identification accuracy of 48 species has reached 99.3%, and has saved more than 8.4 years in calculating time compared to crowdsourced teams of human volunteers [5].

Although AI technology [6] helps us to identify and analyze animal behavior patterns and species, there are still many pre-workers to carry out in intelligent animal care and management. With the IoT technology [7-9] and a large number of animal behavior patterns collected to build a sound sensing environment and database, it is expected to achieve intelligent animal care and management. Therefore, this study is the first to propose a development architecture for the intelligent animal management system based on the IoT and AI. Its main purpose is to automate some tedious procedures for caring animals through the IoT and AI to help animal administrators become more systematically care and management of animals. The proposed architecture is expected to achieve the following goals:

- Automate feeding and environmental control to provide a better living environment and quality for zoo animals.

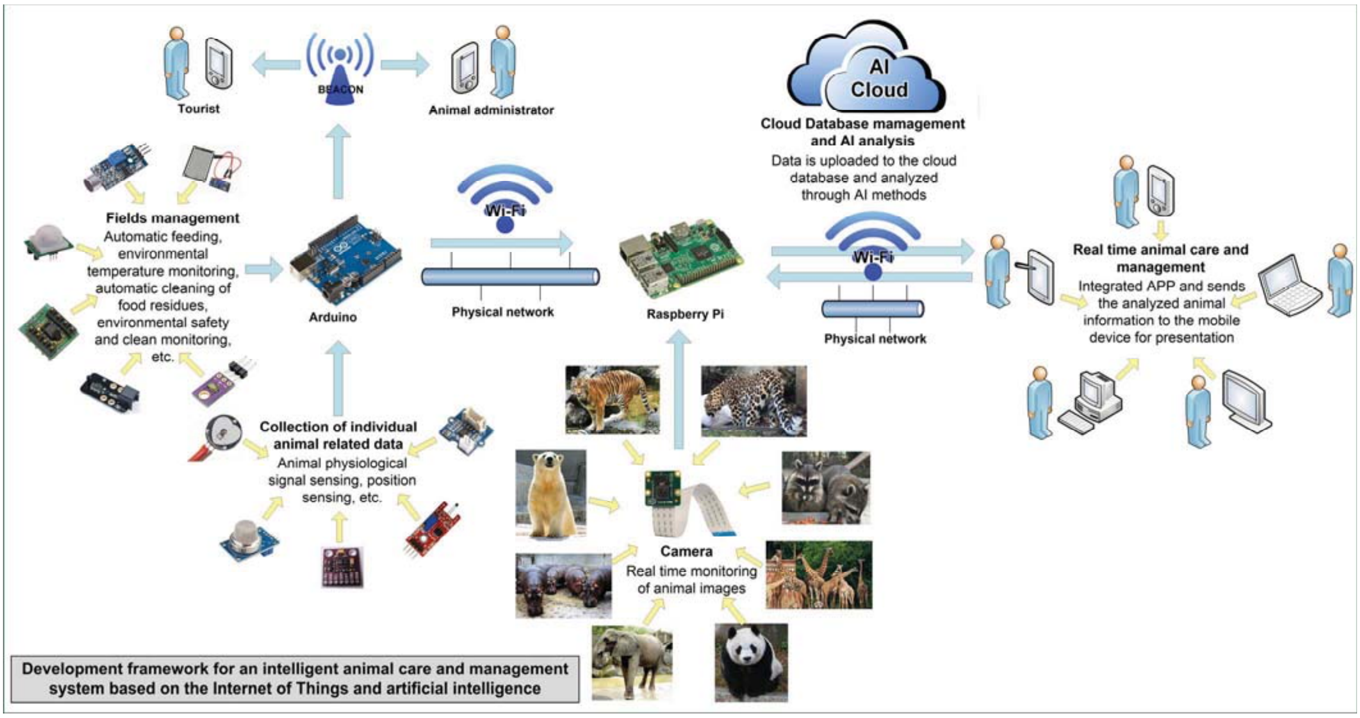

Fig. 1. The development architecture for the intelligent animal care and management system based on the Internet of Things and artificial intelligence.

- Allow animal administrators to take care of animals more efficiently and reduce the workload.
- Improve the management model of zoos with IoT and AI deep learning technology, which will reduce the cost of zoo spending.
- Use network technology to achieve remote animal status monitoring and management to ensure animal safety and health.

II. Development of Intelligent Animal Care and Management Architecture

In order to enable the animal administrators of the zoo to take care of each animal in an efficient manner, the architecture developed by this study is mainly to provide "intelligent management" operation and corresponding measures for the control of the zoo, with particular emphasis on animal administrators learn about animal information. Therefore, IoT technology, AI deep learning technology, cloud database and cloud computing will be used to help animal administrators to clearly understand the individual species, diet, physiological status, mood, feed trough storage, water volume and other information. The labor cost of the zoo is reduced, the efficiency of the animal administrator is improved, and the quality of life of the animals in the zoo is improved and guaranteed. In order to reduce costs and facilitate implementation, the proposed intelligent animal care and management system architecture will be implemented with Arduino and Raspberry Pi. The overall architecture is shown in Fig. 1. The basic system functions are as follows:

A. *Animal biomedical signal sensing and collection*

First of all, we must first use a variety of biomedical sensors to achieve data sensing related to animal biomedical signals, including body temperature sensing, activity sensing, heartbeat sensing, etc. These data will be collected to the cloud database and computing platform for the biomedical data of individualized animals were accumulated and used as follow-up AI analysis.

B. *Environmental sensing and control*

Use various environmental sensing components, such as temperature and humidity sensors, air quality sensors, sound sensors, rain sensors, photometric sensors, etc. to detect the environment of animals and provide different environmental changes for corresponding environmental control and adjustment, for example, when the temperature is higher than 28 degrees, turn on the fan, air-conditioning or sprinkler system in the area to achieve the cooling effect.

C. *Automatic feeding*

With automatic control and automatic food delivery, the animal administrators set the daily fixed feeding time, and when the specified time is reached, the food is automatically sent to the animal's fence.

D. *Automatically clean food residue*

In order to avoid the environmental sanitation caused by the uneaten food or residue breeding of the animal, the food or residue that has not been eaten by the animal must be effectively identified, so that the remaining food can be cleaned by the automatic control and sent to residue area treatment.

E. Real time monitor animal images and tracking their positions

Using a networked camera and positioning system, as long as the animal administrators use a networked communication device, the network can be connected to the camera to real time observe the image and tracking position of the animal.

F. AI deep learning for animal behavior and status to promote health care and analysis

The daily biomedical sensing data and real time images of the animals are sent to the cloud database of AI anytime and anywhere to form a base line of animal health and behavior, and the animal activity status and biomedical sensing data are analyzed immediately through AI. In the event of an abnormality in the animal, the animal administrators are notified and alerted.

This architecture can be implemented using the following related technologies:

III. Methods for implementation of this architecture

This architecture can be implemented using the following related technologies:

A. Beacon

Beacon [10-12] is a technology that uses low energy Bluetooth 4.0, which is a small and inexpensive physical device. We can arrange it in various fields in the zoo to send information to mobile devices or equipment within a certain distance to achieve message transmission to neighboring animals. Use beacon to read the information from the equipment on the animal to achieve the management of animal activity status and health monitoring, and also to achieve micro-positioning, to avoid animal loss and to quickly find animals. In addition, animal administrators can easily manage with mobile devices. When the animal administrator walks around the animal, the animal's various materials can be jumped out of the animal administrator's mobile device or equipment, and the data can be real time returned, allowing the administrator to instantly understand the current animal status and enable the animal to be effectively managed. In addition, visitors can also get introductory information about neighboring animals through their own mobile devices or equipment.

B. Local area network implementation

We can arrange the network in a specific area of the zoo to provide an internet connection of the animal sensing device, and transmit the sensed animal physiological signal and position to the cloud database for storage to achieve big data and AI analysis. Considering the convenience of wireless networks, Wi-Fi [13] is a wireless local area network that allows Wi-Fi enabled devices to connect network from a range of wireless networks to one or more interconnected access points. The local area network is used to transmit the physiological signals and positions measured by the equipment on the animal to achieve the subsequent analysis of the animal activity status and health monitoring management, and also to analyze the animal activity range and understand the animal life habits. In addition, the local area network can be used as a transmission medium for back-end data and front-end application platforms, allowing animal managers to easily control all animal conditions in the zoo using mobile devices or equipment.

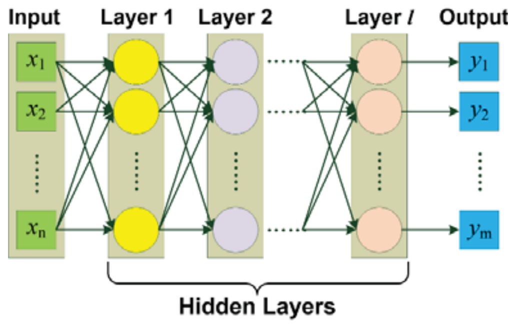

Fig. 2. Neural network architecture.

C. Arduino and Raspberry Pi

Arduino is a low-cost, simple device actuator for building digital devices and interactive objects that interact with the environment to sense and control objects in the physical and digital world [14]. Raspberry Pi is a low-cost, easy-to-obtain, easy to carry, simple to install, stable operation, and can be connected to other peripheral devices. It is a Linux-based single-chip computer that can access the internet and perform some complicated arithmetic processing and analysis. In 2018, NASA launched the open source Open Source Rover project (a reduced version of the Mars Rover Curiosity), using the Raspberry Pi as a control module [15]. The architecture proposed by this research is to use Arduino as the transmission, access control and cloud service related large-scale distributed cloud connection heterogeneous network deployment of sensing data serial port, and use Raspberry Pi as a microcomputer for real-time monitoring and operation analysis to achieve the animal's intelligent management function.

D. Artificial Intelligence (AI)

After receiving the sensory data of animals and the environment, the architecture proposed by this study hopes to help us analyze the behavior and state of animals through AI, so we use deep learning [16] to build the weak artificial intelligence [17] for a special animal allows us to understand the state of animals clearly. The architecture considerations proposed in this study use the deep learning architecture [16, 18, 19] to identify the animal's image motion and the animal's voice emotions to understand the current state of the animal. The basic structure of the neural network is shown in Fig. 2. Each layer has a lot of neurons. The output of the upper layer is the input of the next layer. The number of hidden layers is the depth of the neural network. Get a set of final output.

E. Cloud database and cloud computing

In order to allow animal administrators to conveniently use different platforms or devices to store and use data, and also allow AI to use integrated data for massive data analysis and deep learning, the architecture developed in this study mainly considers the use of cloud data and cloud computing construction [20, 21] intelligent animal care and management system. The benefits of using the cloud platform are: 1) The zoo can flexibly customize the app and adjust the service to suit their needs, and access the cloud service from anywhere through the internet connection. 2) Zoos can speed up application development without worrying about infrastructure costs or maintenance. 3) Developers of the intelligent animal care and management system can focus on application development and regularly update analytical methods to provide the most accurate animal care and management functions for the zoo.

IV. Conclusion

Based on the care and management of animals in zoos, this study proposes a development architecture for the intelligent animal management system based on IoT and AI. The implementation of this architecture will be integrated into beacon, Wi-Fi, local area network Arduino, Raspberry Pi, AI, and various communication technologies such as cloud database and cloud computing. Through the use of these technologies, some cumbersome procedures for caring animals are automated through the IoT and AI to help animal administrators to systematically care for and manage animals, such as sensing the body temperature, mood, activity, and activity status of animals, surrounding environment and position. The structure proposed by this study is currently only a preliminary concept, and there are still many points that need further consideration and revision to meet the needs of the zoo.

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